SOLAR-SYSTEM TESTS OF GRAVITATIONAL THEORIES

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Principal Investigator

Prof. Irwin I. Shapiro

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Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

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Principal Investigator: I. I. Shapiro

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This research is aimed at testing gravitational theory, primarily on an interplanetary scale and using mainly observations of objects in the solar system. Our goal is either to detect departures from the standard model (general relativity) – if any exist within the level of sensitivity of our data – or to support this model by placing tighter bounds on any departure from it. For this project, we have analyzed a combination of observational data with our model of the solar system, including planetary radar ranging, lunar laser ranging, and spacecraft tracking, as well as pulsar timing and pulsar VLBI measurements.

During this period, we have refined our model of the solar system and included many new data in the analysis. Among the model improvements are: increased accuracy in our model of the putative effect of gravitational self-energy on the motion of bodies in case of certain violations of the equivalence principle, increased accuracy of the interplanetary plasma model for uncalibrated data using an eleven-year periodic variation synchronized with the sunspot cycle, reorganization of the set of perturbing asteroids according to modern taxonomic classes, and inclusion of improved asteroid radii based on IRAS and MSX radiometry.

In addition to enhancing our model, we have obtained new data to include in the analysis, primarily tracking data from the Mars Pathfinder and Mars Global Surveyor missions and lunar laser ranging measurements. The additional data have greatly reduced the statistical standard deviations of some of our parameter estimates, though the realistic standard deviations also depend on other factors, such as systematic errors and model imperfections. Although the new Mars data are relatively few in number, they extend the time span of high-precision tracking on the surface of Mars from six years to over 20. As a result, the statistical standard deviation of our estimate of Mars' precession rate nearly halved, and the rest of the parameters in our solar-system model experienced a corresponding, albeit smaller, improvement (about 20% for the relevant asteroid masses, 10% for the semimajor axis of Mars' orbit, and smaller amounts for most other parameters). The addition of the lunar data yielded a more balanced improvement across many parameters.

Another improvement is the inclusion of constraints on the solar gravitational quadrupole moment from helioseismology in the global solar-system analysis. Because this solar quadrupole moment contributes to the classical precession of planetary perihelia, but with a dependence on distance from the Sun that differs from that of the relativistic precession, it is possible to estimate effects simultaneously. However, our interest is mainly in the relativistic effect, and imposing the helioseismology-derived constraint on the quadrupole moment allows the planetary data to contribute more to the gravitational test. This change contributed a dramatic (about ten-fold) decrease

in the standard error of the estimated relativistic component of planetary perihelion advances.

In addition, by considering the contribution of the metric parameters β and γ to the signature of an equivalence principle violation, we have obtained another dramatic (nearly two orders of magnitude) reduction in the standard error for β.

We plan to publish these results soon.